Internal Government Studies

1995

Reports and Presentations

Study Name: Interferometer Thermal Sounder [ITS] - Part II

Team Members: NOAA/ORA(Mitch Goldberg) & NASA/GSFC(Joel Susskind)

IPO POC: D. Blersch

INTERNAL GOVERNMENT STUDIES - FY 1995
Interferometer Thermal Sounder [ITS] - Part II

Presentation/Paper Title	Author(s)	Date
"Final Report to the Integrated Program Office on the Interferomter Thermal Sounder Study: Part II	Susskind, McMillan, Goldberg	15 NOV 95
"IGS Final Presentations for FY95: Interferometer Thermal Sounder (ITS)-[PART II: ITS versus AIRS Tradeoff]"	Goldberg, McMillan, Susskind, Smith, Huang	29 SEPT 95
"IGS Final Presentations for FY95: Interferometer Thermal Sounder (ITS)-Comparative Study of Performance of ITS versus AIRS"	Goldberg, McMillan, Susskind, Smith, Huang	29 SEPT 95
"Interferometer Thermal [Sounder (ITS)-Part II ITS versus AIRS Tradeoff] - Midterm Presentations"	Goldberg, McMillan, Susskind, Smith, Huang	29 JUNE 95
"Primary Differences Between AIRS and ITS"	Joel Susskind	29 JUNE 95
"POES CARD Input for ITS-part II"	Mitch Goldberg	18 APRIL 95
"High Resolution Transmittance for ITS versus AIRS"	Larry McMillan	3 JULY 95
"Preliminary Report on ITS Simulation Study"	Joel Susskind	18 APRIL 95
"ICS Monthly Status Report on ITS"	Mitch Goldberg	18 APRIL 95

Interferometer Thermal Sounder (ITS)
[Part II ITS vs. AIRS Tradeoff]

9/29/95

Participants:

NOAA/ORA: M. Goldberg, L. McMillin
NASAIGSFC: 3. Susskind
CIMSS: W. Smith, A. Huang

OBJECTIVE

To evaluate the ability of the proposed ITS system design to meet temperature and moisture profile requirements specified in the NPOESS IORD and compare these results with other proposed sensors especially AIRS.

Major tasks:

1) Establish radiative transfer models for ITS and AIRS.

2) Generate retrieval results for ITS and AIRS.

3) Assess the ability of the ITS to meet IORD requirements.

Task 1:

Establish radiative transfer models for ITS and AIRS

- Establish line by line transmittance database. - ORA
- Acquire instrument specifications - ORA
- Instrument dependent convolution or Fourier transform/construction of transmittance data for generation of fast models - ORA
- Generation of instrument dependent fast transmittance model - ORA

Accomplishments for Task 1:

- software completed to generate, store, and retrieve transmittances at .01 cm-1 resolution.
- software completed to compute instrument radiances.
- software completed for fast transmittance algorithm for AIRS (spectrometer) and apodized interferometer data.
- obtained most of required hardware.

Task 2:

Generate retrieval results for ITS and AIRS.

- Generate simulated radiance datasets for retrieval algorithm - ORA
- Retrieval performance comparison - ORA/GSFC
- Information content analysis - CIMSS

Accomplishments:

- very little. Need to complete task 1 .

- Procurement for CIMSS task was completed 8/95.

- retrieval software is in place.

Task 3:

Assess the ability of the ITS to meet IORD retrieval accuracy requirements.

- **Final report ORA/GSFC/CIMSS**

COMPARATIVE STUDY OF PERFORMANCE OF ITS VS AIRS

OBJECTIVE:

Assess effects of different instrumental characteristics on accuracy of retrieved products
  T(p) , q(p)

Significant differences between ITS and AIRS

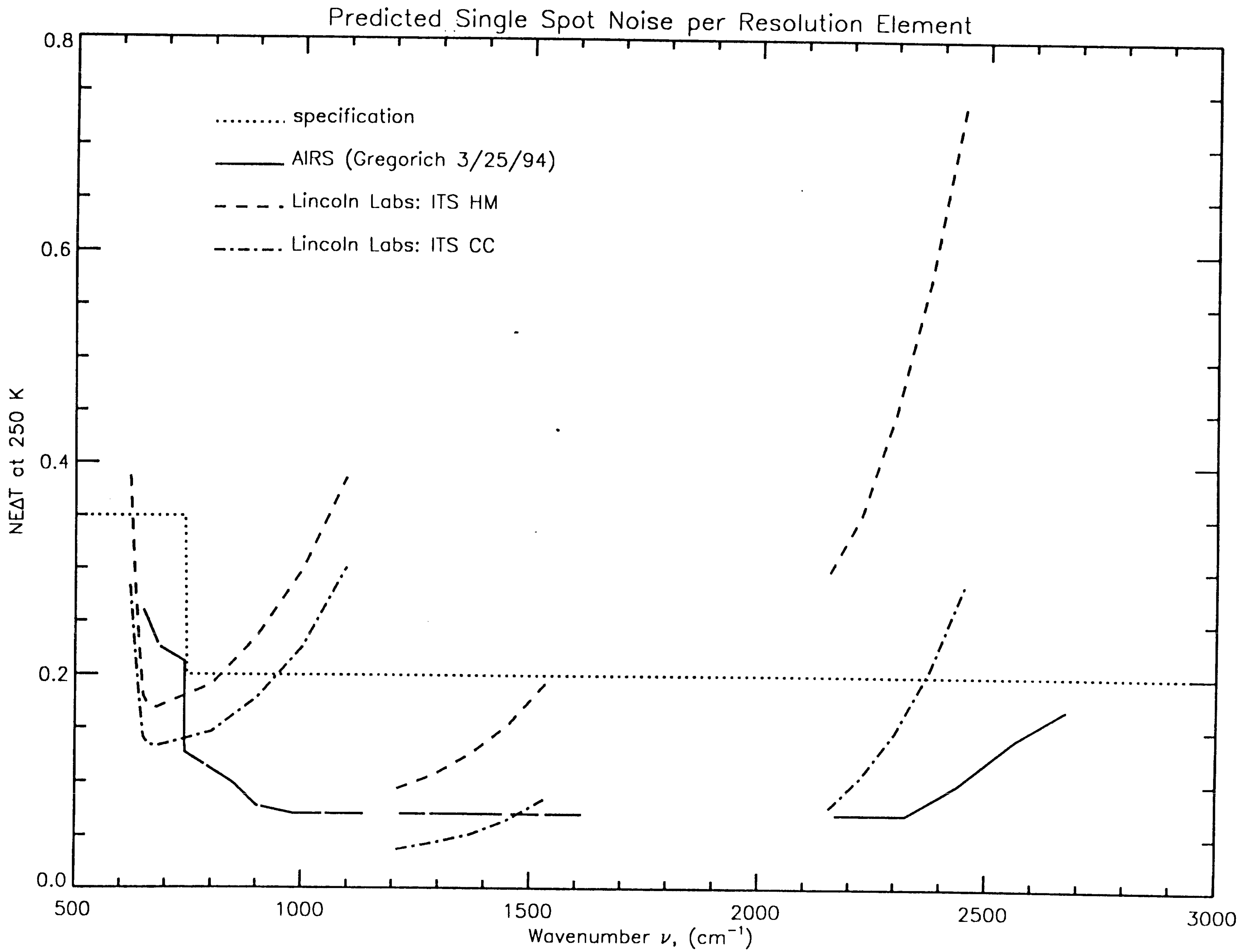
Primary:

- Spectral characteristics
  - Response functions
    - AIRS narrow ($\nu/\Delta\nu \approx 1200$) and localized (95% within $\pm\,\Delta\nu$)
    - ITS either too broad ($\nu/\Delta\nu \approx 600$) or non localized ($\approx$ 40% in $\pm\,\Delta\nu$)
  - Sampling
    - AIRS spectrally sampled twice as often as ITS
  - Domain
    - AIRS extends to shorter wavelengths
- Signal to noise
  - Scene dependence of ITS noise
  - ITS much noisier than AIRS at short wavelengths

Secondary:

- Field of view size
  - Contiguous (AIRS) vs sub-sampled (ITS)
  - Spatial coregistration between channels
    - Places tight constraint on image motion compensation for ITS

Study concentrates on primary issues



Predicted Single Spot Noise per Resolution Element
specification
AIRS (Gregorich 3/25/94)
Lincoln Labs: ITS HM
Lincoln Labs: ITS CC
NEΔT at 250 K
0.0
0.2
0.4
0.6
0.8
500
1000
1500
2000
2500
3000
Wavenumber ν, (cm⁻¹)

SPECTRAL CHARACTERISTICS OF INTERFEROMETER

Measures interferogram of radiance spectrum $I(x)$ for $x = 0 \rightarrow L$ = max delay in cm

Spectral response for channel I $f_I(\nu - \nu_I)$

$f_I(\nu - \nu_I)$ = Fourier transform of $A(x)\,I(x)$ where $A(x)$ = apodization function

$A(x) = 1$ called unapodized

$f_I(\nu - \nu_I)$ is a function of L, $A(x)$

Increasing L makes $f_I(\nu - \nu_I)$ narrower with width $\approx \frac{1}{L}$

Unapodized response function ($\approx \sin y / y$) has narrow central lobe but extended side lobes

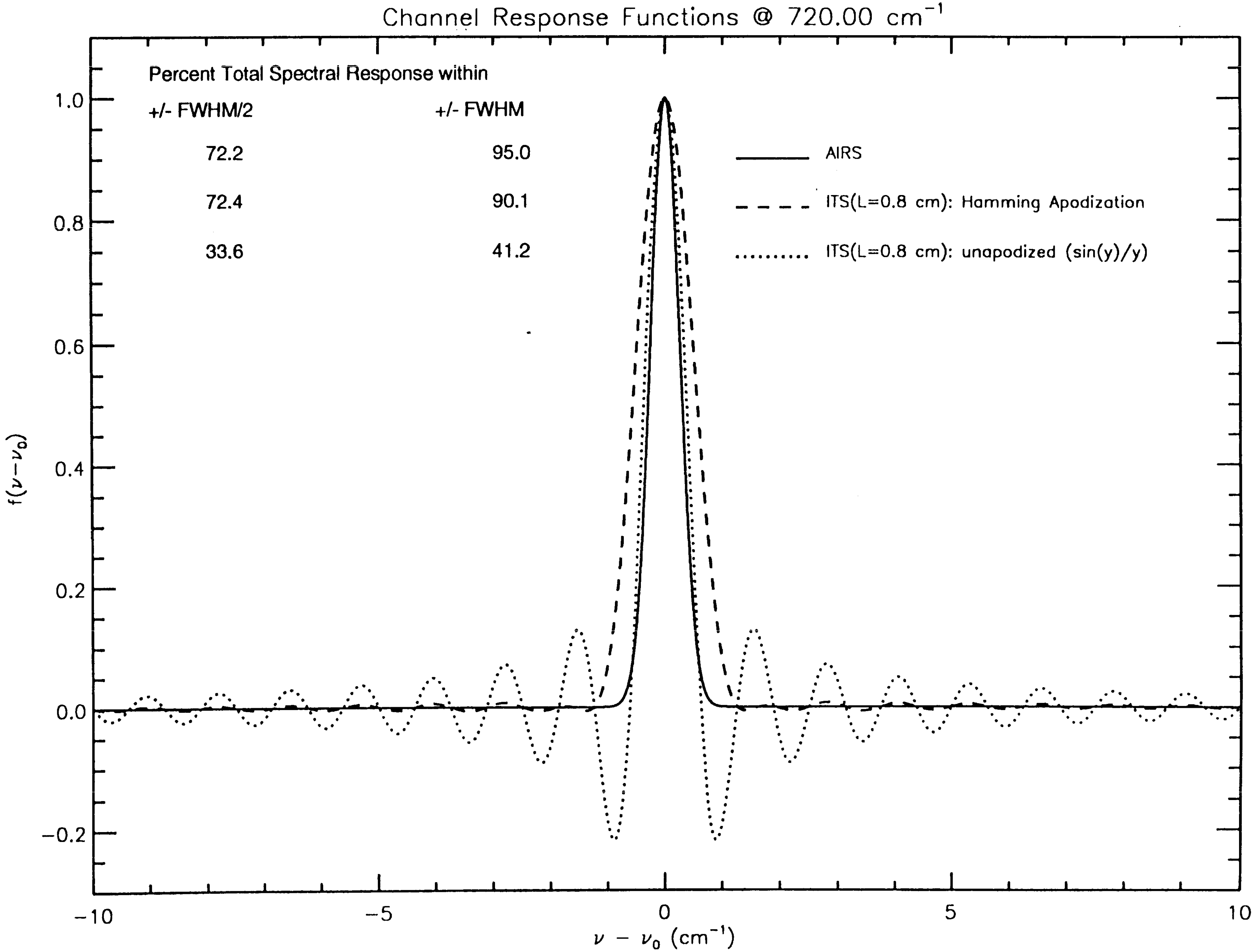
Central lobe contains $\approx 40\%$ of total spectral response

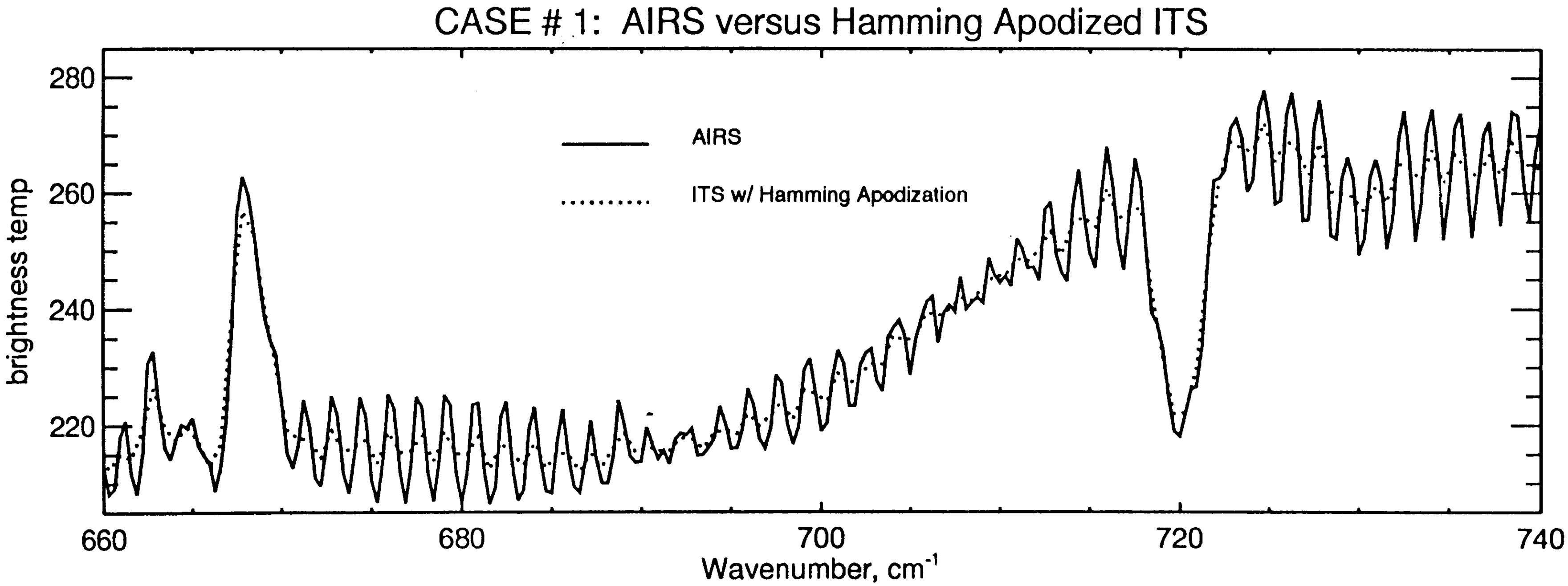
Ideally, want narrow central lobes without side lobes

Spectral resolution <u>and</u> spectral purity

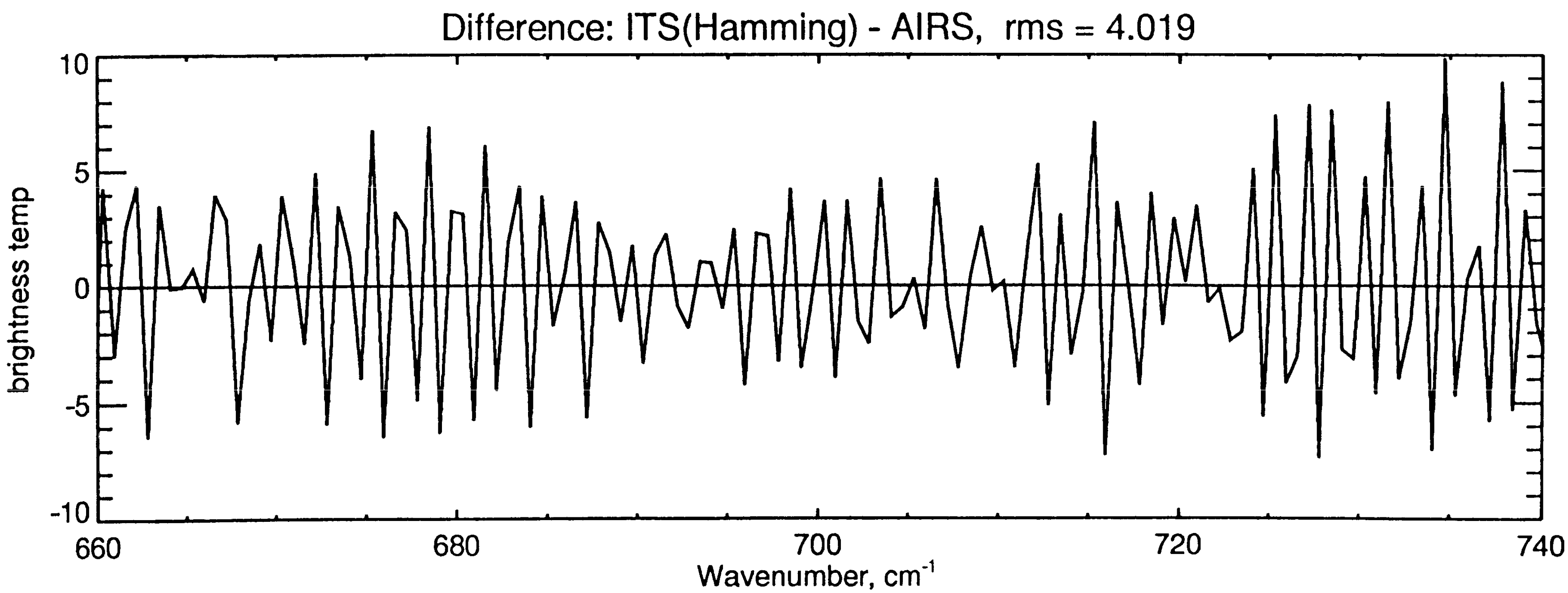
Resolves and isolates spectral regions optimal for sounding

Apodization can reduce side lobes while broadening central lobe

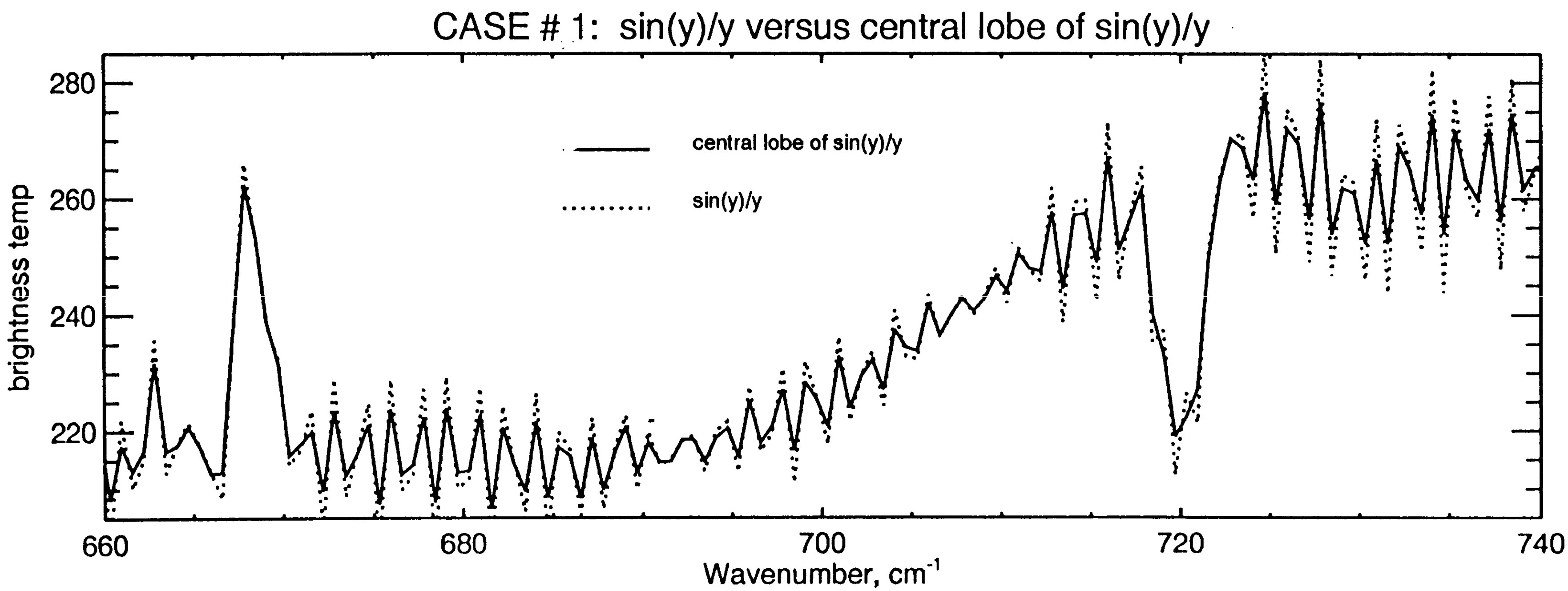

Channel Response Functions @ 720.00 cm⁻¹
Percent Total Spectral Response within
+/- FWHM/2
+/- FWHM
72.2
95.0
72.4
90.1
33.6
41.2
AIRS
ITS(L=0.8 cm): Hamming Apodization
ITS(L=0.8 cm): unapodized (sin(y)/y)
f(ν−ν₀)
ν − ν₀ (cm⁻¹)
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−10
−5
0
5
10

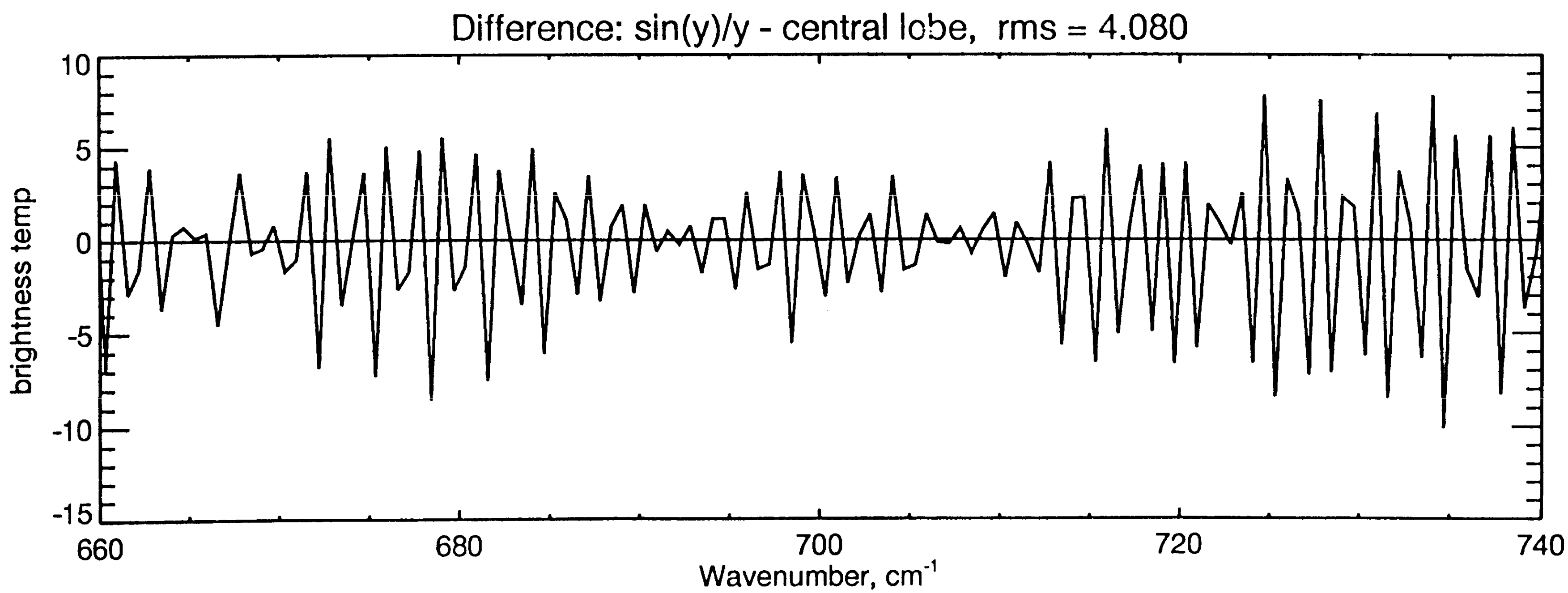


CASE # 1: AIRS versus Hamming Apodized ITS
AIRS
ITS w/ Hamming Apodization
brightness temp
280
260
240
220
660
680
700
720
740
Wavenumber, cm-1



Difference: ITS(Hamming) - AIRS, rms = 4.019
brightness temp
10
5
0
-5
-10
660
680
700
720
740
Wavenumber, cm-1


CASE # 1: sin(y)/y versus central lobe of sin(y)/y
central lobe of sin(y)/y
sin(y)/y
brightness temp
280
260
240
220
660
680
700
720
740
Wavenumber, cm-1


Difference: sin(y)/y - central lobe, rms = 4.080
brightness temp
10
5
0
-5
-10
-15
660
680
700
720
740
Wavenumber, cm-1

POTENTIAL DRAWBACKS OF UNAPODIZED SPECTRAL FUNCTIONS

Must be able to compute radiances accurately with reasonable computation time

- Usual radiance approximation used for narrow band channels does not hold
- Current "exact" code uses monochromatic radiances ≈ 1000 times slower
- Need accurate approximation, reasonable computation time, for practical use

Must be able to account for response beyond central lobe to better than noise limits

- Reduce effects of 4° RMS contamination to better than 0.2° noise
- Potential problem - trace species contamination from distant lines

Retrieval algorithm may need many more channels to account for contamination

- AIRS algorithm uses ≈ 200 out of 2400 channels

For these reasons, unapodized spectra have not been used for retrievals

ORIGINAL STUDY PLAN FOR FY 95

- Perform detailed simulations of instrument observations, with noise

  Ensemble of clear and partially cloudy scenes

- Test effect of apodization on retrieval accuracy

- Perform independent retrievals by both NASA and NOAA

  Tests method dependence of results

  Make simulated data available for others to use as well

- Evaluate results

  Does ITS meet NOAA sounding requirements?

Problem was more complex than originally thought

ACCOMPLISHMENTS SINCE LAST MEETING

SMALL STEPS IN RIGHT DIRECTION

- Formed in-house interferometer specialist team

  Built IRIS and Cassini interferometers

  Providing model to simulate observational noise

  Noise computed based on instrument and scene characteristics

  Will give independent check of Lincoln Lab estimates

- Developed in house expertise on use of appropriate apodization functions

- Wrote joint proposal to do complete end to end simulation study in FY 96

Comparative Performance Study of Interferometer vs. AIRS

submitted to

Integrated Program Office

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Starting Date: October 1, 1995
Support Requested: 10/95 - 9/96 $300K

MILESTONES

BY	
1/31/96	Simulate instrument noise characteristics for ITS, IASI, ...
	Simulate apodized and unapodized spectra for ensemble of cases (clear, partially cloudy)
	Generate rapid algorithm for apodized and AIRS transmittance functions
3/30/96	Perform physical retrievals (NASA, NOAA separately) for clear and cloudy apodized spectra and AIRS spectra. Evaluate results
	Perform regression retrievals for unapodized spectra - NOAA only
6/30/96	Develop computationally efficient rapid algorithm for use with unapodized spectra (hard part)
9/30/96	Perform and evaluate clear and cloudy retrievals for unapodized spectra (NASA and NOAA)
	Have final report

Task 3:

Assess the ability of the ITS to meet IORD retrieval accuracy requirements.

- Final report ORA/GSFC/CIMSS